6. Landforms

Landforms were identified in the ESD (GHD 2019a) as an environmental factor relevant to the Proposal. This section has been prepared to satisfy the requirements of the ESD and the EPA's objective for landforms by describing the landforms within the Development Envelope and regional area and providing an assessment of the potential impacts relating to the implementation of the Proposal.

6.1 EPA objective

To maintain the variety and integrity of significant physical landforms so that environmental values are protected.

For the purpose of EIA, the EPA defines landforms as distinctive, recognisable physical features of the earth's surface having a characteristic shape produced by natural processes. A landform is defined by the combination of its geology (composition) and morphology (form).

6.2 Policy and guidance

EPA Policy and Guidance

- *Statement of Environmental Principles, Factors and Objectives* (EPA 2018b)
- *Instructions on how to prepare an Environmental Review Document* (EPA 2018a)
- *Environmental Factor Guideline: Landforms* (EPA 2016d).

Other policy and guidance

- WA *Environmental Offsets Guidelines* (GoWA 2014)
- WA *Environmental Offsets Policy* (GoWA 2011).

6.3 Required work

The required work for the landform factor as stipulated in the approved ESD and its location within this ERD is documented in Table 6-1.

Table 6-1 Required work for Landforms

Task No	Required work	Section
21	The geology and morphology of the Yalgoo BIF will be described.	Section 6.4
22	The cumulative impacts on landforms from the Proposal in the vicinity of the Development Envelope will be assessed. This will include noting whether these impacts are unknown, unpredictable or irreversible, or combination or contrary to that thereof.	Section 6.6.4
23	An environmental management plan will be prepared that describes the proposed management, and monitoring methods to be implemented to mitigate potential impacts to landforms.	GHD 2020d, Appendix C
24	The residual impacts on landforms for direct, indirect and cumulative impacts will be quantified, after considering avoidance and minimisation measures, and through applying the Residual Impact Significance Model and WA Offset Template in the WA Environmental Offsets Guidelines (GoWA 2014), and the Environmental Offsets Policy (DSEWPC 2012) as appropriate.	Section 6.7

Task No	Required work	Section
25	A mine closure plan will be prepared, consistent with the DMIRS and EPA Guidelines.	GHD 2019c, Appendix D
26	The ERD will demonstrate and document how the EPA's objective for this factor can be met.	Section 6.8.2

6.4 Receiving environment

This section has been prepared in alignment with the requirements of *Environmental Factor Guideline: Landforms* (EPA 2016e).

6.4.1 Supporting landforms technical studies

No supporting studies were completed to inform the assessment of the landforms factor.

A key reference that was used to assess the impacts to landform included the *Strategic Review of the Banded Iron Formation Ranges of the Midwest and Goldfields* (DEC & DoIR 2007).

6.4.2 Regional landforms

The Yogi Mine Site is located within the BIF ranges of the Midwest region of WA, which encompasses the three IBRA regions of Murchison, Yalgoo and Avon Wheatbelt. These are presented in Figure 6-1. The Midwest BIF ranges include the most northern and western BIF ranges located on the Northern Yilgarn Craton. Midwest BIF ranges are isolated ancient ranges set in a predominately flat landscape. They form a relatively small proportion of the total land area of the region and act as unique habitat for flora and fauna due to their different geology, soils and landforms compared to the majority of land in the region. While having some geological similarities to those found in the Pilbara, Midwest BIF ranges are significantly different from the Pilbara formations in terms of the composition of native flora, fauna and ecosystems they support. There are estimated to be approximately 50 to 100 banded ironstone ranges in both the Midwest and Goldfields regions (DEC & DoIR 2007).

The Yogi Mine Site is located in the Yalgoo region, which contains BIF ranges extending northeast, southwest and southeast of the Yalgoo township. The Yalgoo – Mt Singleton greenstone belt is present in this region with extensive BIF outcroppings (Markey and Dillon 2011). There are no BIF ranges in the Yalgoo region which are included in the WA government’s conservation reserve system and generally Midwest BIF ranges have low representation. Exploration and mining tenements cover the BIF landforms throughout the Yalgoo region (DEC & DoIR 2007; Markey and Dillon 2011).

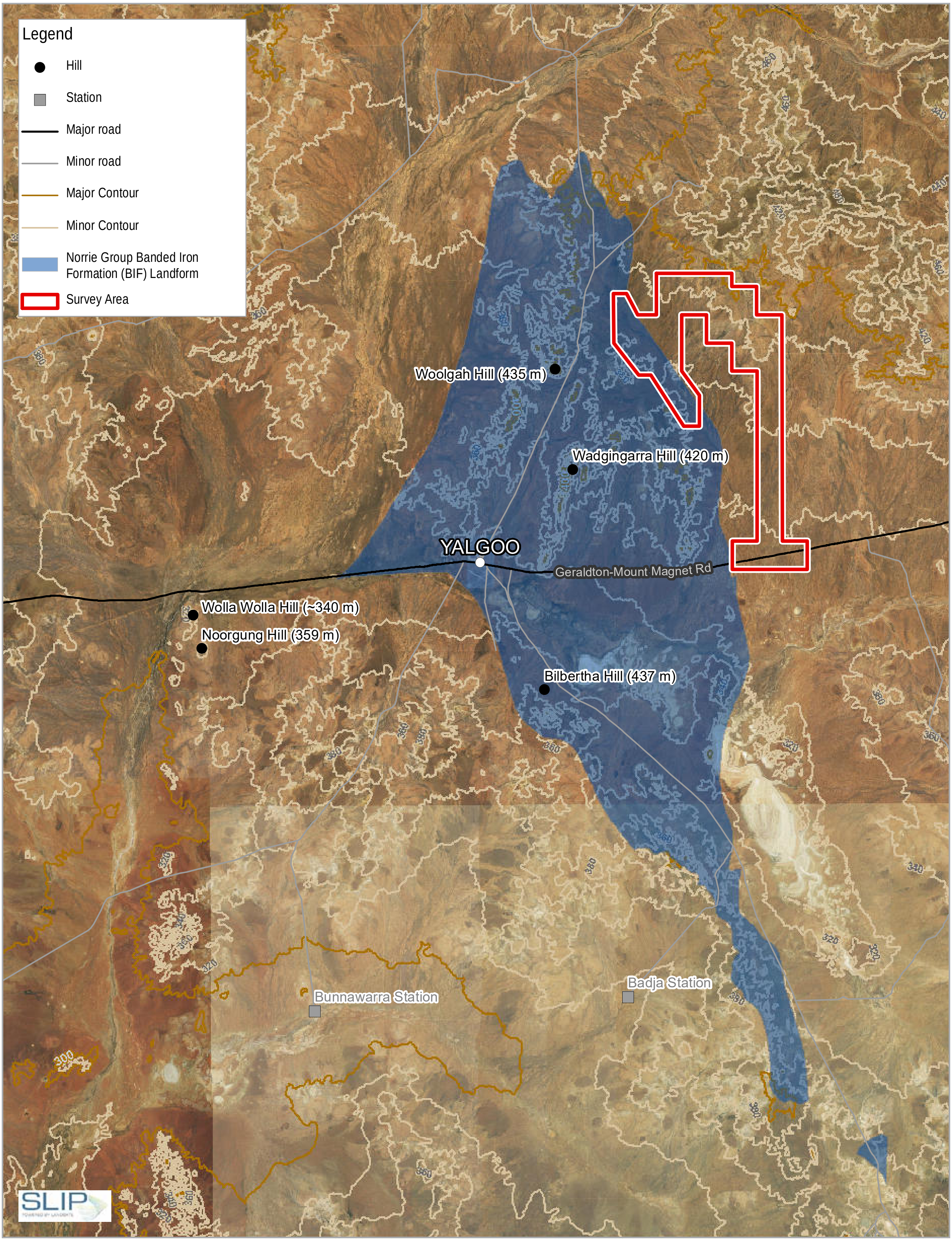
Most of the BIF landform ranges within the Yalgoo region are unnamed, so they are generally referred to by the name of the nearby hills. The landforms range in elevation from 295 m above sea level (ASL) on the outwash plains to over 400 m on the upland greenstone hills and ridges, with the highest points occurring on Bilbertha Hill (437 m) and Woolgah Hill (435 m) (Markey and Dillon 2011). The main BIF landform ranges in the Yalgoo region are summarised in Table 6-2 below.

Soils associated with greenstone ranges are lithosols, and are typically shallow or skeletal (<50 cm) on the ridges, rises and hills, becoming progressively deeper on the lower slopes and outwashes (Henning 1998b as cited in Markey and Dillon 2011). Soils associated with BIF outcrops are relatively rich in nutrients and trace elements with large concentrations of P, K, Cu, Ni, Zn, Mn and Fe (Foulds 1993 as cited in Markey and Dillon 2011).

BIF in the Yalgoo region contain flora taxa of conservation significance and distinctive floristic communities. Notably previous surveys in the Yalgoo region have recorded considerably fewer significant taxa than other more southern BIF ranges, such as Karara–Windaning, Mount Gibson and Koolanooka–Perenjori BIF hills. Lower counts of endemics and uncommon taxa in the Yalgoo region could be a function of reduced diversity of BIF habitats among the relatively more subdued BIF landforms (Markey and Dillon 2011).

Table 6-2 Main BIF range groups in the Yalgoo region (Markey and Dillon 2011)

Name	Location	Extent	Geological description
Woolgah-Wadgingarra Hills	15 km northeast of the Yalgoo township on the Carlaminda and Wagga Wagga Stations	Wadgingarra Hills area spans 17 km north to south, and 4.5 km east to west. Woolgah Hill area consists of a narrow arcuate band of BIF 8 km in length and embedded in mafic rocks.	Prominent uplands, primarily metamorphosed mafics (namely gabbro and diorite). Narrow seams of BIF and other weathered metasediments form low undulating pediments that flank the taller mafic hills.
Gnows Nest Range	18 km southeast of Yalgoo township	Trends in a north-south direction from approximately Minjar Hill to Bilbertha Hill. Spans 30 km north to south and 4 km east to west at the widest point.	Gnows Nest Range has the highest outcroppings of Archaean BIF in the Yalgoo region. Series of parallel strike ridges of exposed BIF interbedded with metavolcanics (primarily basalt but also some dolerite).
Wolla Wolla Hills and Noorgung Hills	21 km southwest of Yalgoo township	BIF ridges are linear (1-1.2 km wide and 2.5-3 km long).	Both are granite domes surrounded by low or barely discernible outcrops of mafics, BIF and associated metasediments. BIF ridges form low hills and undulating pediments surrounded by colluvial deposits on a gently undulating stony plain.



Paper Size ISO A4

0 1 2 3 4 5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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GHD

FI Joint Venture Pty Ltd
Environmental Review Document

Extent of Banded Iron Formations in the Yalgoo Region

Project No. 61-37117
Revision No. 0
Date 12 Jul 2019

FIGURE 6-1

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Print date: 12 Jul 2019 - 14:51

Data source: GHD: Survey Area - 20180622, Norrie Group BIF Landforms - 20190509; AS Markey & SJ Dillon: Hills and Stations Locations - 201101; Landgate: Roads - 20181023, Imagery - Taken September 2012 - Accessed 20181210. Created by: cgverzosa

6.4.3 Local landforms

The Yogi Mine Site is located within the Woolgah-Wadgingarra Hills area (Table 6-2). This area is characterised by the Wadgingarra greenstone belt, which is a series of largely north-south aligned banded ironstone lenses (DEC & DoIR 2007). According to geological mapping (Yalgoo 1:250,000 Geological Series, Sheet SH/50-2, Geological Survey of Western Australia), Archaean aged BIF is present in the far west of the mine site in the location of the orebody and proposed pit (GHD 2018b).

Ecological values

The local BIF landforms of the Yogi Mine Site provide habitat for a range of flora and fauna taxa.

As discussed in Section 5.4, the western portion of the MDE intersects the PEC of the Yalgoo BIF (Priority 1), which is characterised by Yalgoo (Gnows Nest/Wolla Wolla and Woolgah-Wadgingarra) vegetation complexes (banded ironstone formation). Three DBCA Priority listed flora species associated with the BIF range were recorded in the survey of the MDE. Approximately 450 individuals of *Acacia subsessilis* (Priority 3), 1,185 individuals of *Acacia speckii* (Priority 4) and 53 individuals of *Dodonaea amplisemina* (Priority 4) were recorded on the BIF range. Based on field observations and other studies *A. subsessilis* and *A. speckii* extend beyond and occur outside of the MDE, with *A. speckii* recorded in large numbers on neighbouring BIF rises (GHD 2019b, Maia 2011).

As discussed in Section 9.4, six broad fauna habitat types were identified in the MDE, which includes the BIF Ridgelines. The BIF Ridgelines are considered to be moderate to high value fauna habitat and comprise 1,249.57 ha of the MDE. The rocky slopes and ridgeline would provide core habitat for the Long-tailed Dunnart (*Sminthopsis longicaudata*) and Gilled Slender Bluetongue (*Cyclodomorphis branchialis*), which is known from the region and likely to occur in the MDE. The conservation significant Western spiny-tailed skink (*Egernia stokesii badia*), was recorded in one BIF location and is likely to persist in other small outcropping areas present. Peregrine Falcon (*Falco peregrinus*) may also utilise these areas for foraging. Notably, the BIF hills were recorded to have few areas of outcropping, but rather were covered in pebbles and small scattered rocks on very hard substrates. This environmental structure reduces the opportunity for species to hide or create refugia and therefore reduces the species present (GHD 2020b).

6.5 Potential impacts

Potential direct and indirect impacts to landforms include the following:

- Direct :
  - Alteration to landform structure (either temporary or permanent) (Section 6.6.1)
- Indirect:
  - Alteration to ecological function of the landform (either temporary or permanent) (Section 6.6.2)
  - Impacts on environmental values of the landform (either temporary or permanent) (Section 6.6.3).

6.6 Assessment of impacts

6.6.1 Alteration to landform structure (either temporary or permanent)

Woolgah Hill (435 m) and Wadgingarra Hill (420 m), located in the vicinity of the MDE, are among the highest BIF landforms in the Yalgoo BIF range, but they are not the tallest BIF landforms in the Yalgoo region. Bibertha Hill (437 m) south of Yalgoo township exceeds them in height (Markey and Dillon 2011). Woolgah-Wadgingarra Hills are not isolated unique landforms, but rather exemplify other BIF landforms in the broader Yalgoo region (Section 6.4.2). Overall the landform value of the Woolgah-Wadgingarra Hills in terms of their elevation are not considered to be significant or unique at a regional scale.

In the western portion of the MDE (M 59/740), a mine pit, overburden landform and supporting infrastructure will be constructed, which coincide with the location of the Woolgah-Wadgingarra Hills BIF area due to the location of the ore body. The disturbance footprint will be designed to reduce impacts to the landform structure, but impacts from construction and operations would be permanent. As part of the mine closure process progressive rehabilitation will occur which will diminish the temporary visual impacts of mining. An objective of the mine closure process (GHD 2019c, Appendix D) is for the site landscape to reflect regional topography, so it is expected that the overburden landform will be rehabilitated to a height that is consistent with the BIF landforms in the region.

A maximum of approximately 1,205 ha of the Woolgah-Wadgingarra Hills area could be affected as a result of the Proposal. This represents 4% of the Woolgah-Wadgingarra Hills BIF landform area (proportion of the mapped extent of the Yalgoo BIF PEC as a surrogate for the landform area). The overwhelming majority of the landform will not be disturbed by the Proposal. Therefore, although alteration to the BIF landform structure would be permanent, the alteration is not considered to be significant.

6.6.2 Alteration to ecological function of the landform (either temporary or permanent)

The maximum area of the Yalgoo BIF PEC (Priority 1) to be removed by the Proposal is approximately 1,041 ha. Therefore 96.5% of the Yalgoo BIF PEC associated with the Woolgah-Wadgingarra Hills area, will remain. This shows that the majority of the PEC will not be affected. In addition, other Yalgoo BIF PECs associated with landforms southeast and southwest of Yalgoo township, as well as other BIF PECs (Gullewa BIF, Priority 1 and Minjar and Chulaar Hills, Priority 1) will not be affected by the Proposal.

As discussed in Section 6.4.3, two conservation significant flora species associated with the BIF range (*Acacia subsessilis*, *Acacia speckii*) which were recorded in the MDE are also known to occur outside the MDE. The maximum area of the BIF Ridgeline fauna habitat to be cleared within the MDE is 357.48 ha, which means that only 28.61% of the habitat will be removed and the majority of the BIF Ridgeline habitat will remain. While the BIF represents habitat for multiple species of conservation significance (i.e. the Long-tailed Dunnart, Gilled Slender Bluetongue, and Western Spiny-tailed Skink), none of the species rely solely on this habitat to persist in this region as discussed in detail in Section 9.4. On the consideration that the majority of the PEC will remain as a result of the Proposal and that conservation flora and fauna are known to be present outside the BIF habitat within the MDE, it is expected that any alteration to the ecological function of the BIF landform would be temporary and not overall significant.

6.6.3 Impacts on environmental values of the landform (either temporary or permanent)

The environmental values of the BIFs in the Yalgoo region are lesser than other BIFs in WA. Yalgoo BIF have considerably fewer significant flora taxa, lower counts of endemics and uncommon taxa than other BIFs in WA (Section 6.4.2). While the BIF within the MDE represents habitat for multiple species of conservation significance (i.e. the Long-tailed Dunnart, Gilled Slender Bluetongue, and Western Spiny-tailed Skink), none of the species rely solely on this habitat to persist in this region. The Woolgah-Wadgingarra Hills are not isolated landforms with unique landform structures, but rather exemplify the BIFs in the Yalgoo region. The environmental values of only one BIF landform range (Woolgah-Wadgingarra Hills) within the broader Yalgoo region would be affected by the Proposal. In addition mining tenements are present across the Yalgoo BIF region and none of the Yalgoo BIF landforms are protected under the WA state conservation estate (DEC & DoIR 2007). Therefore, although impacts to the environmental values of the BIF landform would be permanent, it is not be expected for the impacts to be significant.

6.6.4 Cumulative impacts

There are no identified cumulative impacts to the Woolgah-Wadgingarra Hills as there are currently no other projects currently operation on this BIF landform. Woolgah-Wadgingarra Hills BIF landforms located outside the MDE and other Yalgoo region BIF landforms located southeast and southwest of the Yalgoo township will not be affected.

There will be a permanent loss of ecological function for conservation significant flora and fauna known to occur in the BIF landform area of the MDE. However, BIF landform occur outside the MDE. Overall the loss of this BIF landform is not considered significant given the relatively undisturbed condition of the remainder (undisturbed from mining activities).

The majority (96.5%) of the Yalgoo BIF PEC associated with the Woolgah-Wadgingarra Hills area will remain following implementation of the Proposal. Conservation significant flora and fauna habitats are not restricted to the BIF landform within the MDE. Impacts to ecological function will be temporary, but they are not considered to be significant. The BIF landforms of the Woolgah-Wadgingarra Hills have lower environmental value than others BIFs in WA.

6.7 Mitigation

The mitigation hierarchy (avoid, minimise, rehabilitate) has been applied to this proposal in relation to landforms.

The inherent impacts that must be managed include:

- Alteration to landform structure
- Alteration to ecological function of the landform
- Impacts on environmental values of the landform
- Management and monitoring measures for the above impacts are well practiced and understood in the industry, and are considered to be effective. FIJV will continue to offset the clearing of native vegetation and fauna habitat via removal of the BIF landform through progressive rehabilitation of areas disturbed by mining activities.

Proposed mitigation measures to address the above potential impacts to landforms are outlined in Table 6-3.

Table 6-3 Mitigation measures for impacts to landforms

Impact	Mitigation measures
Alteration to landform structure	**Avoid** • Disturbance footprint designed to reduce disturbance to BIF landform structure. **Minimise** • An internal ground disturbance procedures and permitting system will be implemented so that disturbance footprint is adhered to. • Conduct clearing in accordance with permit and clearing procedure. • Landforms (pit, overburden, waste rock, dry waste) are to be inspected for geotechnical stability and erosional stability. The landforms will be

Impact	Mitigation measures
	inspected to confirm the integrity of bunds, fencing and indicators of unauthorised entry. The mine site will also be inspected to confirm that land features outside of restricted areas do not present an unacceptable safety risk to persons, stock animals or native fauna, such as the presence of eroded gullies or exposed hazardous materials. • Inspections are to include, but are not limited to: – visual inspection – wall and/or slope stability – bund integrity – capping integrity – seepage checks – road condition – erosion impacts • **Rehabilitate** • Progressive rehabilitation of disturbed areas will be undertaken in accordance with the MCP so that site landscape will reflect regional topography.
Alteration to ecological function of the landform	**Avoid** • Disturbance footprint designed to reduce clearing of and disturbance to Yalgoo BIF PEC (Priority 1), as well as conservation significant flora and fauna. • **Minimise** • Conduct clearing in accordance with permit and clearing procedure. • Undertake a variety of management measures during all phases of the project to prevent negative impacts to flora and fauna. • **Rehabilitate** • Progressive rehabilitation of disturbed areas will be undertaken in accordance with the MCP so that native vegetation is re-established. • Top soil will be stockpiled for use in revegetation. • Following the replacement of weed and dieback free topsoil direct seeding with native species will be undertaken: – Where possible, tube stock will be used in rehabilitation to increase the likelihood of establishment and retain the genetic integrity of the area – Seeding will be undertaken in the optimal season, identified by restoration practitioners, specific to the suite of species selected. Rate of seed application will be determined in consultation with revegetation/restoration practitioners and/or qualified ecologist – Fertiliser, containing nitrogen and phosphorus, will be used to encourage the growth of native seedlings at a rate determined by a revegetation/restoration practitioner – Use of fertilisers in revegetation will be tested prior to broad-scale application to determine the effect on native and weed species abundance local to the area.

Impact	Mitigation measures
	– Review mine plan to determine landform dimensions at end of mine life.
Impacts on environmental values of the landform	**Avoid** • Disturbance footprint designed to reduce clearing of and disturbance to Yalgoo BIF PEC (Priority 1), conservation significant flora and fauna, as well as the landform structure. **Minimise** • Internal ground disturbance procedures and permitting system will be implemented so that disturbance footprint is adhered to. • Conduct clearing in accordance with permit and clearing procedure. • Undertake a variety of management measures during all phases of the project to prevent negative impacts to flora, fauna and landform structure. • **Rehabilitate** • Progressive rehabilitation of disturbed areas will be undertaken in accordance with the MCP so that native vegetation is re-established and the site landscape reflects regional topography.

6.8 Predicted outcome

6.8.1 Residual impact

A summary of residual impacts after the implementation of the proposal and the application of the mitigation measures outlined in Table 6-3 above is provided in Table 6-4.

Table 6-4 Predicted outcomes for impacts to landforms

Impact	Residual impact
Alteration to landform structure	Some permanent impacts to the BIF landform structure would occur from mine construction and operations given that the BIF is located on the western portion of the MDE where the ore body located and the mine pit is proposed. However, ground disturbance will be rehabilitated and landforms established in the location of the BIF (i.e. overburden facility) will be rehabilitated to reflect regional BIF topography.
Alteration to ecological function of the landform	Temporary alteration to the ecological function may occur due to the removal of Yalgoo BIF itself, including conservation flora and fauna habitat.
Impacts on environmental values of the landform	Permanent impacts to the environmental values of the BIF landform may occur due to alteration of the landform structure and the removal of the Yalgoo BIF PEC, including conservation flora and fauna habitat.

6.8.2 Assessment against the EPA objective

Following completion of the assessment and the residual impact outlined in Table 6-4, it is considered that the disturbance to the BIF landform required for the implementation of the Proposal will not have significant residual impacts. As such, it meets the objective for this factor such that variety and integrity of significant physical landforms so that environmental values are protected.

6.8.3 Offsets

Based on the expectation that the clearing and removal of the BIF landform within the MDE will not have significant residual impacts, no offsets are proposed.

7. Subterranean Fauna

7.1 EPA objective

To protect subterranean fauna so that biological diversity and ecological integrity are maintained.

For the purposes of EIA, the EPA defines subterranean fauna as animals living their entire lives below the surface of the earth. These include stygofauna and troglofauna.

7.2 Policy and guidance

EPA Policy and Guidance

- *Statement of Environmental Principles, Factors and Objectives* (EPA 2018b)
- *Instructions on how to prepare an Environmental Review Document* (EPA 2018a)
- *Environmental Factor Guideline Subterranean Fauna* (EPA 2016e)
- *Technical Guidance Terrestrial Subterranean Fauna Surveys* (EPA 2016f).

Other policy and guidance

- *WA Environmental Offsets Guidelines* (GoWA 2014)
- *WA Environmental Offsets Policy* (GoWA 2011)
- *Environmental Offsets Policy* (DSEWPC 2012).

7.3 Required work

The required work for the subterranean fauna factor as stipulated in the approved ESD and its location within this ERD is documented in Table 7-1.

Table 7-1 Required work for Subterranean Fauna

Item	Required work	Section
27	A desktop study will be undertaken to document the regional context of the subterranean fauna of the Proposal area including, but not limited to, existing regional subterranean fauna surveys, and assessment of the likely presence and characteristics of subterranean fauna habitat.	Section 7.4.1
28	A Level 2 survey will be conducted inside and outside areas subject to direct and indirect impacts, in accordance with EPA Environmental Factor Guideline - Subterranean Fauna (EPA 2016e), Technical Guidance - Subterranean Fauna Survey (2016) and Technical Guidance - Sampling Methods for Subterranean Fauna (EPA 2016f).	Section 7.4.1
29	The results of the relevant subterranean fauna survey will include mapping of the distributions of species in relation to the proposed disturbance (including groundwater drawdown), and of the geology or hydrology predicted to support subterranean fauna habitats (including its extent outside the Development Envelope).	Section 7.4
30	Habitat prospectively will be discussed to demonstrate habitat connectivity within and outside the proposed disturbance area.	Section 7.4.3
31	Figure(s) will be provided showing the extent of subterranean fauna habitat in relation to the Proposal and species distribution.	Figure 7-1 and Figure 7-2 (Section 7.4.2)
32	The extent of direct, indirect and cumulative impacts as a result of implementation of the Proposal will be described and assessed during both construction and operations to subterranean fauna,	Section 7.6

Item	Required work	Section
	taking into consideration the significance of subterranean fauna and subterranean fauna habitat. This will include noting whether these impacts are unknown, unpredictable or irreversible, or combination or contrary to that thereof.	
33	The residual impacts to subterranean fauna in regards to relevant impacts from the Proposal will be quantified, after considering avoidance and minimisation measures, and through applying the Residual Impact Significance Model and WA Offset Template in the WA Environmental Offsets Guidelines (GoWA 2014), and the Environmental Offsets Policy (DSEWPC 2012) as appropriate.	Section 7.8
34	Management measures for the Proposal will be identified to ensure residual impacts to subterranean fauna are not greater than predicted.	Section 7.7
35	The significance of any significant residual impacts on the identified environmental values will be determined by applying the Residual Impact Significance Model (page 11) and WA Offset Template (Appendix 1) in the WA Environmental Offsets Guidelines (GoWA 2014). Spatial data will be provided defining the area of significant residual impacts.	Section 7.8
36	Where significant residual impacts remain, and relate to MNES, an appropriate offsets package will be provided, consistent with WA Environmental Offsets Policy and Guidelines and the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy and . Spatial data will be provided defining the area of significant residual impacts.	Section 7.8
37	The ERD will demonstrate and document how the EPA's objective for this factor can be met.	Section 7.8

7.4 Receiving Environment

This section has been prepared in alignment with the requirements of *Environmental Factor Guideline: Subterranean Fauna* (EPA 2016e).

7.4.1 Supporting subterranean fauna technical studies

A technical study of the subterranean fauna of the development envelope was completed as part of the development of this ERD. A summary of the technical study completed to date is provided in Table 7-2.

Additional surveys for troglofauna (prior to the finalisation of the 'Response to Submissions' on the public comment received on the ERD) will be undertaken inside and outside of the mine footprint area. The results of these surveys will be provided to the EPA prior to them completing the assessment of the Proposal.

Table 7-2 Summary of supporting subterranean fauna studies

Report Title Author (Month Year)	Target	Location	Date	Summary	Survey area relevance to Proposal development envelope
Dual Phase Survey for Subterranean Fauna for the Yogi Magnetite Project, Yalgoo, Western Australia Invertebrate Solutions Pty Ltd 2020 (Appendix B)	Stygofauna and troglofauna	MDE, and several locations on the west, east, northwest and south of the MDE	August to October 2018 and November 2019	A desktop assessment was completed to identify the presence of troglofauna and stygofauna in the MDE and surrounding area through a search of the of the Western Australian Museum database. Suitable geological characteristics that would support subterranean fauna were also identified through the desktop review of geological, geotechnical and hydrogeological information available for the study area. A detailed (Level 2) phase 1 survey was completed between August and October 2018 of the relevant project tenements and in areas outside the project tenements. The detailed (Level 2) phase 2 survey was completed in November 2019, sampling a mixture of previously sampled bores and additional bores which were drilled for water exploration purposes in April 2019. Troglofauna survey retrieved 28 litter traps in suitable groundwater bores in the phase 1 survey and 26 traps in 18 previously sampled bores in phase 2. The dual phase survey retrieved a total of 54 the 62 traps deployed, with 8 traps irretrievable. The phase 1 stygofauna survey sampled 22 groundwater bores and the phase 2 survey sampled a total of 23 bores (a mixture of previously sampled bores and additional bores	The survey area includes and extends beyond the MDE; providing an overview of the potential presence of subterranean fauna in the local area.

Report Title Author (Month Year)	Target	Location	Date	Summary	Survey area relevance to Proposal development envelope
				which were drilled for water exploration purposes). A total of 45 stygofauna samples were undertaken in the two surveys. The survey methods used for stygofauna included using a net that was dropped to the base of the bore and pulled through the water column several times.	

7.4.2 Subterranean fauna diversity

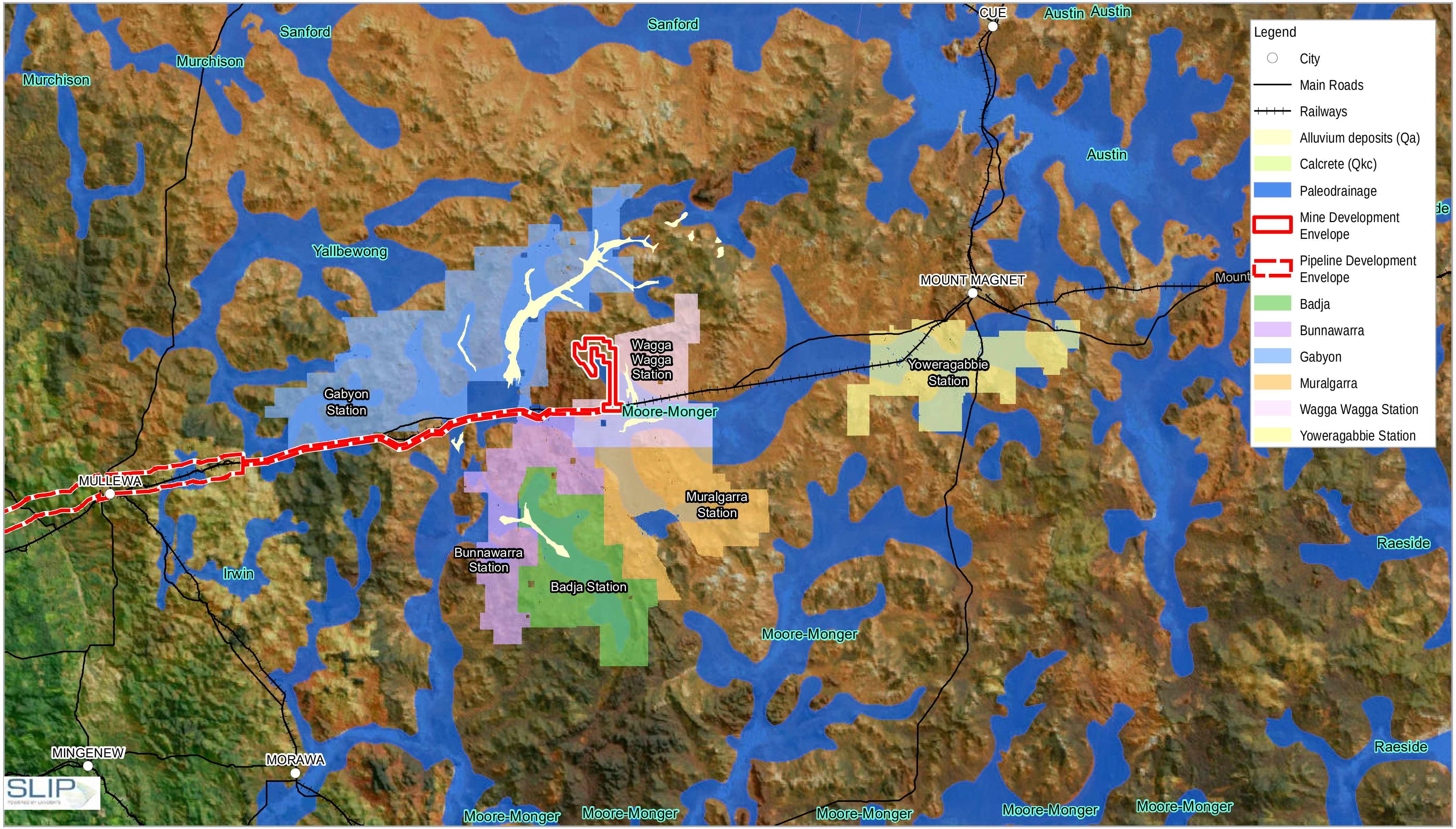
7.4.2.1 Stygofauna communities

As summarised in Table 7-2, a dual phase survey (Invertebrate Solutions 2020) was completed for subterranean fauna within the MDE. The study included a desktop assessment of records held by the Western Australia Museum and a Level 2 site fauna trapping and sampling component.

No previous records of stygofauna are present within the databases of the Western Australian Museum (Invertebrate Solutions 2020). Five stygofauna communities, all listed as Priority 1 Ecological Communities (under the *Biodiversity Conservation Act 2016*) are known to occur in the calcrete areas (Table 7-3 and Figure 7-1) in the region (Enviroworks Consulting 2017, as cited in DBCA 2017 as cited in Invertebrate Solutions 2020) (Table 7-3). All these calcretes were listed due to the presence of stygobiont Dytiscid diving beetles that occur in virtually every calcrete in the Mid West (Cooper *et al*. 2002; Humphreys 2005; Watts and Humphreys 2003; Watts and Humphreys 2004), and although these species make up only some of the stygobiontic fauna there is often little known of the rest of the community for the majority of sites.

Table 7-3 Stygofauna communities listed under State legislation

Calcrete Name	Community Name	Conservation listing	Buffer (m)	Distance from Yogi tenements (km)
Badja	Badja calcrete groundwater assemblage type on Moore palaeodrainage (Badja Station)	Priority 1	2000	38.6
Bunnawarra	Bunnawarra calcrete groundwater assemblage type on Moore palaeodrainage (Bunnawarra Station)	Priority 1	2000	36.0
Gabyon	Gabyon calcrete groundwater assemblage type on Moore palaeodrainage (Gabyon Station)	Priority 1	2000	22.1
Muralgarra	Muralgarra calcrete groundwater assemblage type on Murchison palaeodrainage (Muralgarra Station)	Priority 1	2000	33.3
Wagga Wagga and Yalgoo	Wagga Wagga and Yalgoo calcrete groundwater assemblage type on Yalgoo palaeodrainage (Wagga Wagga Station), and Moore palaeodrainage (Yoweragabbie Station)	Priority 1	2000	4.7



Paper Size ISO A4

0 5 10 15 20

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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FI Joint Venture Pty Ltd
Environmental Review Document

Subterranean Fauna
Ecological Communities

Project No. 61-37117
Revision No. 0
Date 12 Jul 2019

FIGURE 7-1

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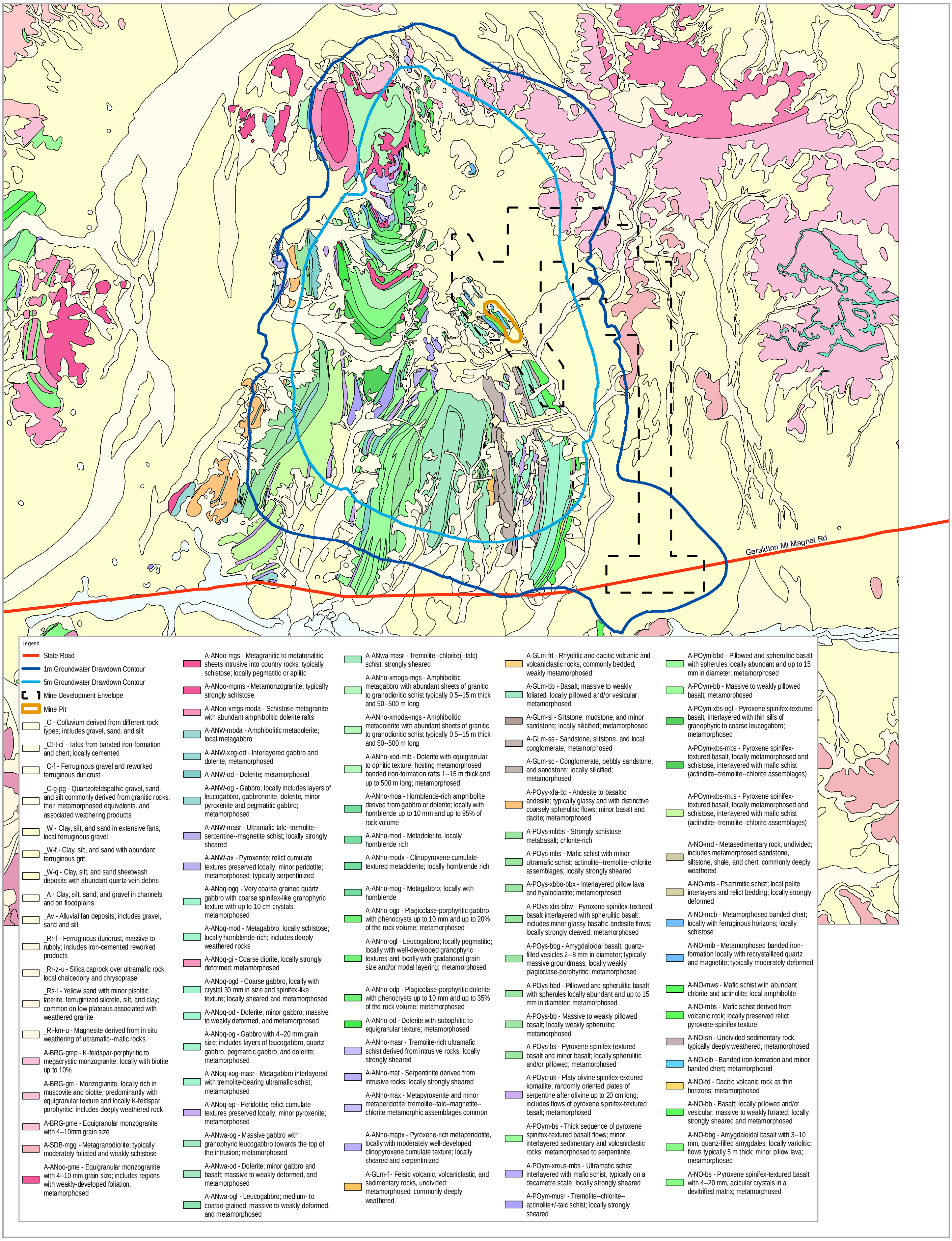
Data source: GHD: Pipeline Development Envelope, Mine Development Envelope; DAFWA: Pastoral Boundaries - 20160916; Landgate: Roads - 20190128, Railway - 20190304, Imagery. Created by: cgverzosa



Paper Size ISO A4

0 1 2 3 4 5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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FI Joint Venture Pty Ltd
Environmental Review Document

Project Area Surface Geology

Project No. 61-37117
Revision No. 0
Date 24 Oct 2019

FIGURE 7-2

G:\61\37117\GIS\Maps\Working\Environmental Review Document\6137117_007-2_ProjAreaSurfaceGeology_revA.mxd
Print date: 24 Oct 2019 - 12:42

Data source: Data source: MRWA: State Roads - 20171024; GHD: Drawdown contours; DMP: 1:100,000 Geological Map - Yalgoo (2241) - 20151008; Landgate: Imagery. Created by: cgverzosa

7.4.2.2 Troglofauna species diversity

The dual phase survey of troglofauna included the placement of 30 traps deployed in phase 1, with 28 retrieved, while phase 2 deployed 32 traps with 26 retrieved. The locations of bores sampled for troglofauna and the results from the dual phase survey are shown in Figure 7-3.

The phase 1 survey recorded three individuals from two classes and two families that may represent obligate subterranean forms Two specimens of an undescribed *Philoscid* isopod were recorded from two locations (YRC2 and YORC128) on the within the footprint of the proposed mine pit. The Philosciidae sp. ‘yalgoo’, exhibited troglomorphic characters including loss of pigmentation and reduced eyes that would indicate that the species is an obligate subterranean form (Invertebrate Solutions 2020). The other specimen, Unixemus sp., was noted to be a surface species with likely wide distributions (Invertebrate Solutions 2020).The phase 2 survey recorded 30 individuals from two classes and four families that may represent obligate subterranean forms.

Details of the troglofauna recorded from the phase 1 and phase 2 survey are provided in Table 7-4 and Figure 7-3.

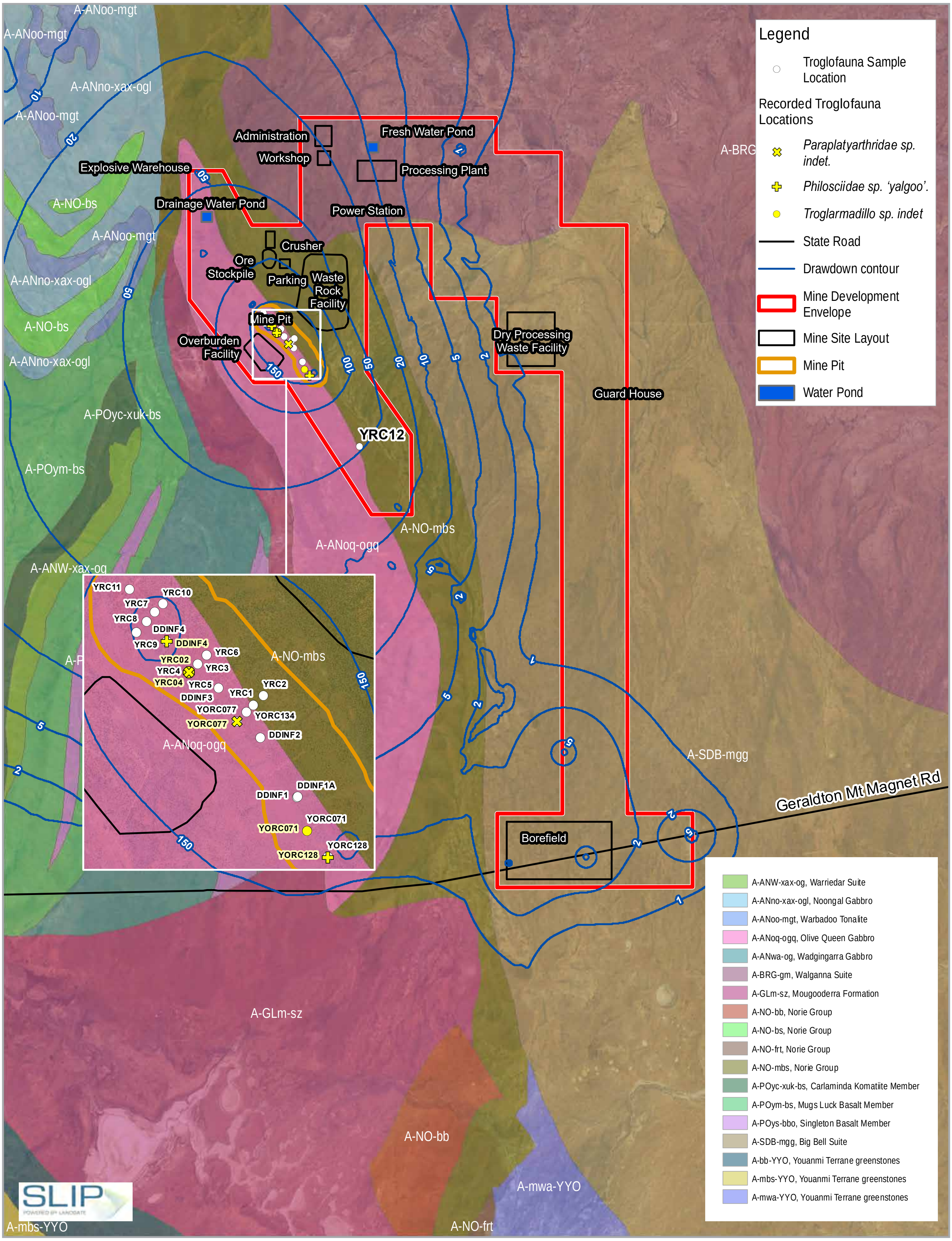
7.4.2.3 Stygofauna species diversity

The dual phase stygofauna survey saw a total of 45 bores sampled (22 in phase 1 and 23 in phase 2). The location of the bores sampled for stygofauna is shown in Figure 7-4.

The samples collected during the phase 1 survey returned stygofauna from two classes, three orders, three families and six genera. The greatest diversity was among the copepods with two orders, two families, four genera and four species recorded. One of the specimens identified, *Schizopera yalgoo* n. sp. has not been recorded previously, and following review of relevant databases and phylogeny, is considered endemic and a stygobiont (Karanovic and Karanovic 2018, as cited in Invertebrate Solutions 2020). This specimen was found in Lazy Well located on the southern side of the MDE, and in the vicinity of the paleochannel (Invertebrate Solutions 2020).

The phase 2 survey recorded 17 individuals of one species of ostracod, *Sarscypridopsis ochracea* from two of the 24 bores sampled. This was the same species previously recorded from the Melville Well during the phase 1 survey (Invertebrate Solutions 2020).

Details of the stygofauna recorded from the phase 1 and phase 2 survey are provided in Table 7-4 and Figure 7-4.



Paper Size ISO A4

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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GHD

FI Joint Venture Pty Ltd
Environmental Review Document

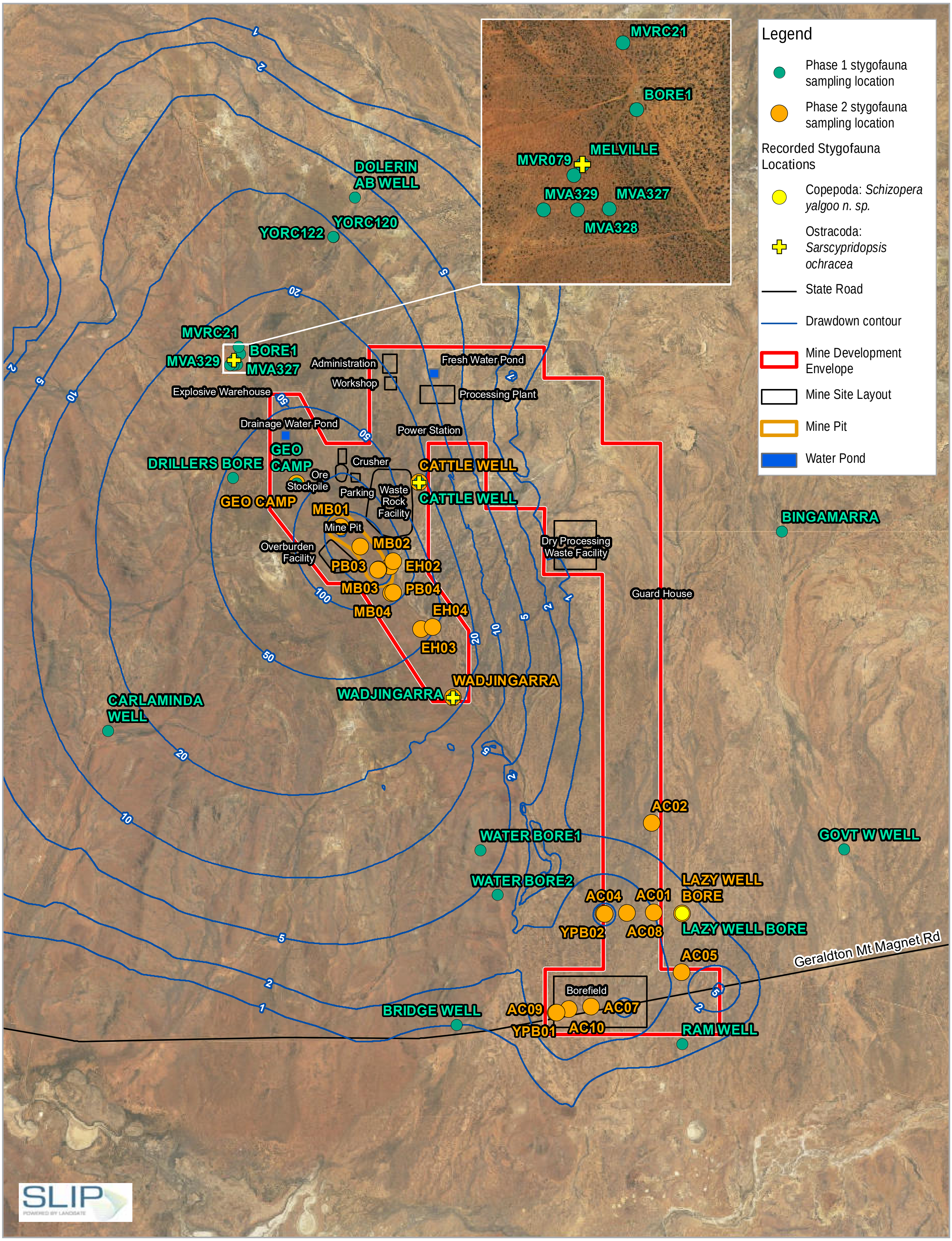
Troglofauna Sampling Locations

Project No. 61-37117
Revision No. 0
Date 06 Apr 2020

FIGURE 7-3

G:\61\37117\GIS\Maps\Working\Environmental Review Document\6137117_007-3_TroglofaunaSamplingLocations_rev0.mxd
Print date: 06 Apr 2020 - 11:09

Data source: Data source: MRWA: State Roads - 20171024; FIJV: Mine Tenements, Mine Site Layout, Development Envelope, Pipeline Development Envelope - 20171025; Landgate: Imagery. Created by: bjones2



Paper Size ISO A4

0 1 2 3 4 5

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Environmental Review Document

Stygofauna Sampling Locations

Project No.	61-37117
Revision No.	0
Date	02 Apr 2020

FIGURE 7-4

G:\61\37117\GIS\Maps\Working\Environmental Review Document\6137117_007-4_StygofaunaSamplingLocations_rev0.mxd
Print date: 02 Apr 2020 - 16:37

Data source: Data source: MRWA: State Roads - 20171024; FIJV: Mine Tenements, Mine Site Layout, Development Envelope, Pipeline Development Envelope - 20171025; Landgate: Imagery. Created by: cgverzosa

Table 7-4 Subterranean fauna within or in proximity to the Mine Development Envelope

Higher Order	Genus and species	Sample Locations	Survey Timing	Endemism / Specialisation Status	Geology/Habitat Distribution
Stygofauna					
Crustacea: Ostracoda: Podocopida: Cyprididae	Sarscypridopsis ochracea	Melville Well Cattle Well Wadjingarra Well	Phase 1 & 2	Known from South Africa and WA. First ever male specimens from Australia	Located up to 18.3 m bgl, likely to be the superficial aquifer. Colluvium - rock fragments, gravel, sand and silt This geology is closely aligned with the Woolgah-Wadgingarra Hills on which the impacted BIF landform occurs. This geology is highly fragmented and not well connected to surrounding habitat. This geology is surrounded by other forms of fragmented geology including laterite, felsic rocks and mafic rocks. This indicates that movement of stygofauna through this area may not be liberal.
	Cyprididae sp.	Bingarmarra Well, Bridge Well, Cattle Well, Wadjingarra Well	Phase 1	Juvenile specimens, identification requires adults (probably Sarscypridopsis ochracea – see above)	Located up to 12 to 25 m bgl, likely to be the superficial aquifer. Sand - alluvial, eolian, eluvial, on Qcf and Alluvium - sand, silt and gravel deposits. This geology is well presented across the MDE and the local region.
Crustacea: Copepoda: Cyclopoida: Cyclopidae	Apocyclops dengizicus	Lazy Well	Phase 1	Cosmopolitan.	Located up to 17.1 m bgl, likely to be the superficial aquifer. Sand - alluvial, eolian, eluvial, on Qcf. This geology is closely aligned with the identified paleochannel, and is represented extensively in the area and is well connected to the surrounding habitat.
	Mesocyclops brooksi	Bingarmarra Well	Phase 1	Widespread, stygophilic species	Located up to 17.1 m bgl, likely to be the superficial aquifer. Sand - alluvial, eolian, eluvial, on Qcf and Alluvium - sand, silt and gravel deposits. This geology is well presented across the MDE and the local region.
	Metacyclops laurentiisae	Melville Well	Phase 1	Found throughout Murchison region of WA, stygophilic species	As discussed above regarding Melville Well.
Crustacea: Copepoda: Harpacticoida: Miraciidae	Schizopera yalgoo n. sp.	Lazy Well	Phase 1	New species, likely endemic	Located up to 17.1 m bgl, likely to be the superficial aquifer. Sand - alluvial, eolian, eluvial, on Qcf and Alluvium - sand, silt and gravel deposits. This geology is well presented across the MDE and the local region.
Troglofauna					
Crustacea: Isopoda: Armadillidae	Troglarmadillo sp. indet	YORCO71	Phase 2	Know from various locations in the northern half of Western Australia	Located within BIF ridgeline within the mine pit Fine-grained sedimentary rocks, some felsic volcanic rocks - most of unit is weathered and Colluvium - rock fragments, gravel, sand and silt.
Crustacea: Isopoda: Paraplatyarthridae	Paraplatyarthridae sp. indet	YRC04 YORC077	Phase 2	All Western Australian Paraplatyarthridae are at least partially subterranean and commonly show restricted distributions.	Located within BIF ridgeline within the mine pit Fine-grained sedimentary rocks, some felsic volcanic rocks - most of unit is weathered and Colluvium - rock fragments, gravel, sand and silt.
Crustacea: Isopoda: Philosciidae	Philosciidae sp. 'yalgoo'.	YRC02 YORC128 DDINF4	Phase 1 and Phase 2	Undescribed species with troglomorphic characters present indicating an obligate subterranean species.	Located within BIF ridgeline within the mine pit Fine-grained sedimentary rocks, some felsic volcanic rocks - most of unit is weathered and Colluvium - rock fragments, gravel, sand and silt.
Arachnida: Pseudoscorpionida	Chelifieridae? Sp. indet juvenile	YRC03	Phase 2		Located within BIF ridgeline within the mine pit Fine-grained sedimentary rocks, some felsic volcanic rocks - most of unit is weathered and Colluvium - rock fragments, gravel, sand and silt.
Myriapod: Diplopoda: Polyxenida	Unixemus sp.	YRC12	Phase 1	Surface species with likely wide distributions	Located within the BIF ridgeline, south of the proposed mine pit. BIF ridgeline comprising rocks and crevices that comprise this area.

7.4.3 Subterranean fauna habitat

7.4.3.1 Troglofauna habitat

The habitat assessment for potentially restricted species within the MDE is based upon available geological and hydrogeological reports, surface geology maps and the Geological Survey of Western Australian 1:250,000 Map of Yalgoo (Figure 7-1 and Figure 7-2).

Suitable habitat for troglofauna is highly likely to occur in calcrete areas, where the upper unsaturated portions of the calcrete provide suitable conditions for troglofauna in the extensive interconnected void networks found in calcrete outcrops. The BIF located in the pit void has a moderate likelihood for troglofauna habitat based on other BIF outcrops in the region. Suitable habitat for Troglofauna identified is described in Table 7-5. The area of BIF ridgeline as suitable troglofauna habitat has been inferred from the *Fauna Assessment* (GHD 2020b).

7.4.3.2 Stygofauna habitat

Habitat for stygofauna is characterised primarily via the desktop geological assessment due to the absence of core logs and photos from the Project area. The desktop assessment combined with the Phase 1 sampling results would indicate that stygofauna are more likely to occur within shallow alluvial aquifers. However, only very limited sampling of deeper aquifers has been undertaken and the presence of stygofauna taxa or suitable habitat for stygofauna cannot be excluded from other aquifers.

The habitat assessment for potentially restricted species within the MDE is based upon available geological and hydrogeological reports, surface geology maps and the Geological Survey of Western Australian 1:250,000 Map of Yalgoo (Figure 7-1 and Figure 7-2). The geology of the MDE has been summarised in Table 7-5 below.

Areas of alluvial and colluvial sediment represent the majority of the MDE (5,936.38 ha and 404.15 ha respectively) and are considered to be known stygofauna habitat. This includes the paleochannel located on the southern side of the MDE. There are limited extents of calcrete or laterite geologies present within the MDE (18.61 ha) which are considered likely stygofauna habitat.

The remainder of the development envelope is represented by sedimentary and igneous rock, silicate minerals and weather rock, with represents a fractured rock aquifer. These geologies are typically tight formations and although there may be some weathering and fractures throughout, they are not anticipated to represent optimal habitat for stygofauna.

Table 7-5 Subterranean fauna habitat

Unit Type	Geology / Habitat	Extent within MDE	Suitable subterranean fauna habitat	Troglofauna Sample Bore IDs	Stygofauna Sample Bore IDs
Alluvial sediments	Sand, silt and gravel; Sand - eolian; on edges of lakes and drainage lines; also as dunes; Sand - alluvial, eolian, eluvial	5936.38	Known for stygofauna if within the saturated zone. Low for troglofauna.		Bingarmarra Well; Bridge Well; Cattle Well; Lazy Well
Paleochannel	Moore and Murchison palaeodrainage systems		Moderate/High Stygofauna Nil for troglofauna (below watertable)		
Calcrete / laterite	Laterite - concentration of goethite and hematite: some cemented gravel deposits; Quartz-kaolin grit, cemented limonite gravel;	18.61	High/Definite for stygofauna High for troglofauna (above watertable)		
Colluvial sediments	Rock fragments, gravel, sand and silt	404.15	Known for stygofauna if within the saturated zone. Low for troglofauna	YRC12	Melville Well; Wadjingarra Well
BIF	Medium grained dolerite	1487.44	Moderate for stygofauna Moderate for troglofauna (above watertable)		
Igneous rock	Felsic volcanic with some mafic rocks – medium to coarse grained: gabbro, diorite, granophyre and granite,		Low for stygofauna. Low for troglofauna (above watertable).	All bores (except YRC12)[1]	
Sedimentary rock	Sedimentary rocks	347.34			
Silicate mineral	Tremolite, tremolite-chlorite / talc rocks	16.77	Low for stygofauna.		

Unit Type	Geology / Habitat	Extent within MDE	Suitable subterranean fauna habitat	Troglofauna Sample Bore IDs	Stygofauna Sample Bore IDs
Weathered (sedimentary) rock	Interpreted as fine grained sedimentary rocks, some felsic volcanic rocks	19.41	Low for troglofauna (above watertable).		

1. These geologies have been merged to reflect the tight and variable geology that composes the BIF landform and determining their precise location is difficult to discern

Aquifer characteristics

Groundwater levels were generally found to be around 20 metres below ground level (m bgl), occurring at a reported elevation of approximately 355-365 m Australian Height Datum (GHD 2019e). Groundwater was inferred to occur within a fractured rock aquifer situated near and immediately below the base of weathering, typically 10 to 30 m bgl (GHD 2019e). Falling head tests completed on two open holes indicated an inferred hydraulic conductivity of 1.4 to 1.8 x 10^{-7} m/s (0.01-0.02 m/d) (GHD 2019e).

The figure indicated that groundwater levels are broadly consistent with topography, and indicate a dominating groundwater high point coincident with the topographic high located approximately 40 km north east of the Pit area. Data for the Project area indicates that groundwater is generally flowing in the southern direction, discharging to the low ground present along the current drainage line of the Salt River. There is a groundwater divide, consistent with the catchment divide, located along the higher ground present to the immediate west of the Pit area.

There are two main aquifers identified within the MDE, this includes the paleochannel aquifer, which is largely an alluvial aquifer present within existing and paleo-drainage areas. Drilling completed for the Proposal identified that this aquifer was typically silt/fine grained sand dominated, and present up to a maximum depth of around 70 m in the far south of the MDE. Under the BIF landform, and further west, a fractured rock aquifer has been identified, with the majority of groundwater flow occurring in the upper zone of weathering (up to a nominal depth of around 60 m) (GHD 2019e).

Groundwater properties

Groundwater properties, for stygofauna sampling locations, indicate suitable conditions for stygofauna throughout the MDE and wider area (Table 7-6).

The groundwater quality at Lazy Well (the location where Schizopera yalgoo n. sp. was identified) has been included to allow assessment of groundwater suitability across the MDE.

Groundwater across the area was typically fresh to brackish, with salinity generally lowest in groundwater wells with a standing water levels at a greater depth below ground level. The highest salinity was measured in a groundwater well located outside of the MDE to the south. Groundwater is considered to be an aerobic, oxidising environment across the MDE and slightly alkaline. These conditions indicate suitable conditions for stygofauna.

Groundwater quality between the paleochannel (southern area of the MDE) and the pit area (northwest area of the MDE) were noted to have a significant difference in quality (GHD 2019e). Salinity was notably higher in the paleochannel area, with an average TDS of 10,000 mg/L, compared to just over 800 mg/L recorded in the pit area (GHD 2019e). Groundwater with a salinity greater than 5000 mg/L is considered unsuitable for stock watering. The relatively fresh groundwater (low salinity) found at the pit bores is indicative of those bores being close to a groundwater recharge area.

Nutrient concentrations are generally quite low for throughout the MDE, however the pit area was noted to have a higher concentrations of nitrogen, predominately as nitrate. This may be related to naturally occurring sources and/or surface water runoff (resulting in recharge) in areas that are occupied by cattle. Metal concentrations were generally quite low for all test bores with no exceedance of any assessment criteria.

Table 7-6 Groundwater quality from bores sampled (Invertebrate Solutions 2020)

Parameter	Electrical Conductivity (µS/cm)	Total dissolved solids (mg/L)	pH	Oxidation reduction potential (mV)	Temperature (℃)	Depth to water (m bgl)
Phase 1 (August 2018)						
Minimum	814	407	6.87	39.5	20.01	6.1
Maximum	23,920	11,960	8.09	50.1	26.24	35.4
Groundwater properties of Lazy Well	8,905	4,451	8.04	48.1	20.01	12.8
Phase 2 survey (November 2019)						
Minimum	1,143	643	6.44	-244.5	24.05	8.4
Maximum	20,050	10,030	7.55	77.7	27.73	27
Groundwater properties of Lazy Well	7,224	3,603	7.06	65.9	25.16	12.6

7.4.4 Limitations of subterranean fauna assessment

The following limitations are recognised with regard to the subterranean fauna studies completed to date:

- Due to the absence of vertical bores within the mining pit void no troglofauna scrape sampling was able to be undertaken.
- No systematic core photos of the site were available for examination to assist in the determination of subterranean fauna habitat presence and/or extent (Invertebrate Solutions 2020).

7.5 Potential impacts

Potential direct and indirect impacts to subterranean fauna include the following:

- Direct:
  - Loss or degradation of habitat or species population from construction and operations (Section 7.6.1)
- Indirect impacts resulting in loss of potential habitat and species populations:
  - Abstraction of groundwater (Section 7.6.2)
  - Changes to hydrological regimes and water quality (Section 7.6.3)

– Groundwater contamination (Section 7.6.4)
– Loss of food/nutrient sources (Section 7.6.5).

Assessment of each of these potential impacts is included below. Mitigation to address these potential impacts and predicted outcomes is presented in Section 7.7.

7.6 Assessment of impacts

7.6.1 Loss or degradation of habitat or species population

The following assessment of potential impacts to subterranean fauna habitat is based on the assessments completed to date. As noted in Section 7.4.1, an additional subterranean fauna survey is currently underway, the results of which and the assessment of potential impacts to subterranean fauna will be provided as an addendum to this ERD.

The current assessment of potential impacts has considered the extent of the suitable habitat outside the proposed areas of impact (i.e. pits) and the presence of geological barriers (e.g. dykes) that may be prohibitive to troglofauna or stygofauna movement. Surface geology, bore log data and geological cross sections were utilised to inform this habitat assessment.

7.6.1.1 Troglofauna

Impacts due to mining are determined partially by the distribution of species and their abundance outside the impact area and partly by the rarity of the individual species. Having an extensive distribution suggests that troglofauna species have moderately high dispersal ability, either through inhabiting well connected subterranean habitats in which they migrate or through possessing a surface dispersal phase in their life cycles.

Of the two troglofauna taxa detected from sampling at the MDE, one troglofauna taxa is known only from proposed pit boundaries (albeit on the surface) (Figure 7-3). Based on current taxonomic and ecological information, and the likely extent of suitable habitats for troglofauna beyond pit boundaries, the following taxa are regarded as;

- Low risk - *Unixemus* sp.;
- High risk - *Philosciidae* sp. ‘yalgoo’.

Two of the three troglomorphic isopod species have been recorded at multiple locations, indicating there is connectivity throughout the sampled area and is likely to extend well beyond the proposed mining area. The species (Paraplatyarthridae: Paraplatyarthrus? sp. indet. and Armadillidae: Troglarmadillo sp. indet.) have been described as having a ‘restricted distribution’ as they have only been recorded from within the proposed mine pit, where all sampling has occurred. This is not to say their distribution does not extend more widely, especially in the same geological units that provided habitat for these species, which extends far beyond the proposed mine pit and entire project area to the north and south (as shown in Figure 7-3) (Invertebrate Solutions 2020).

In addition, due to the relatively shallow depths at which the species were recorded (often <10m below ground level) the species may be utilising the “Mesovoid Shallow Substratum”, i.e. the interconnected network of voids and cavities within the overlaying colluvium and alluvium to increase their potential habitat far beyond the area sampled. Therefore, it is likely that both these troglobiont isopods has potential habitat and distributions within the local region (Invertebrate Solutions 2020).

Potential impacts of other activities associated with mining on subterranean fauna (such as impacts of blasting on surrounding areas) are poorly understood. However, the impacts of these activities are expected to dissipate rapidly outside the mine pit. Consequently, such activities are more likely to cause population reduction, if they have an impact, than to threaten persistence of the species as a whole. Secondary impacts of percussion from blasting may be summarised as follows. Subterranean fauna may potentially be affected by shock waves propagated from blasting and through altering underground structures (usually through rock fragmentation and collapse of voids). The effects of blasting are often referred to in grey literature but are poorly quantified and the ecological impacts are not described. Any effects of blasting are likely to dissipate rapidly with distance from a mine pit. Blasting is not considered as a significant impacting activity beyond the mine pit boundary.

As indicated in Figure 7-2, and summarised in Table 7-7, mining will result in the direct removal of approximately 147 ha of the surface geological units in the Mine Pit, of which 102 ha are considered to be potential subterranean fauna habitat. As shown in Figure 7-2 and Table 7-7 these surface geologies, which are potential subterranean fauna habitat, extend well beyond the Mine Development Envelope.

Table 7-7 Anticipated removal of surface geology within the mine pit

Geological unit	Unit name	Area of removal	Likelihood of habitat suitability
_A: Clay, silt, sand, and gravel in channels and on floodplains	Alluvial unit	0.17	Likely habitat
_C-f: Ferruginous gravel and reworked ferruginous duricrust	Colluvial unit	50.41	Likely habitat
_W-f: Clay, silt, and sand with abundant ferruginous grit	Sheetwash unit	51.42	Likely habitat
A-ANoq-gi: Coarse diorite, locally strongly deformed; metamorphosed	Olive Queen Gabbro	0.01	Possible suitable habitat
A-ANoq-og: igneous granitic	Olive Queen Gabbro	9.65	Possible suitable habitat
A-NO-cib: Banded iron-formation and minor banded chert; metamorphosed	Norie Group	19.97	Possible suitable habitat
A-NO-mbs: Mafic schist derived from volcanic rock; locally preserved relict pyroxene-spinifex texture	Norie Group	12.37	Possible suitable habitat
A-NO-mts: Psammitic schist; local pelite interlayers and relict bedding; locally strongly deformed	Norie Group	3.91	Possible suitable habitat
Total		**147.91**	

Based on current geological information, the primary habitats for troglofauna (i.e. BIF ridgeline) are not limited to the deposits to be developed by this Proposal. The area of BIF Ridgeline, which is likely to provide suitable habitat for any of the troglofauna species occurring within the deposits, are well represented within the Woolgah-Wadgingarra Hills area and the proposed area affected by mining is negligible is comparison to the overall area of the formation present in the wider region (as discussed previously in Section 6.6). These geological formations extend well beyond the boundaries of the MDE and as such, do not represent isolated troglofauna habitat. As also shown in Figure 6-1, the majority (96.5%) of the Yalgoo BIF PEC associated with the Woolgah-Wadgingarra Hills area, will remain.

Although a degree of heterogeneity within and between these strata would be expected, there is no evidence of any clear geological barriers between the various suitable habitat layers inside and outside of the Yogi deposit. Therefore, given the continuous nature of these geological formations troglofauna (if present) are likely to extend into continuous habitat throughout the region.

Given the extent of other primary habitats (nearby surficial detritals: alluvium and colluvium, pisolite and calcrete deposits) and other secondary habitats (fractured and weathered lower members of the BIF of the Woolgah-Wadgingarra Hills where sufficiently fractured and above the water table), it would be reasonable to expect that troglofauna, if present, would be well represented across the region. It should be noted that Invertebrate Solutions (2020) considers the current known occurrence of the single potentially troglobitic species from only within the proposed deposit / pit boundaries (Table 7-4) is partly attributed to available sampling locations rather than being an accurate representation of species ranges (Section 7.4.2). With this in mind, any troglofauna species occurring within the deposits (including the single troglomorphic species detailed in Table 7-4) may occur in the geological formations (assessed as likely providing suitable habitat) that extend beyond the boundaries of the deposits and are well represented in the wider region. Assumptions made on the likely wider distribution of potentially troglobitic species in a range of habitats beyond the proposed deposit boundaries are consistent with EPA guidance. The potential troglofauna habitat to be removed by the proposed mine pit is only 3.5% of the total volume of these geological units, with 96.5% remaining in the local area. As such, troglofauna are considered to be at low risk of impact from mining.

7.6.1.2 Stygofauna

Of the six stygofauna taxa detected from sampling within the MDE, one is potentially endemic stygofauna taxon and is known only from southern end of the MDE, from the sand and alluvium deposits that comprises the paleochannel in that region. This taxon was regarded as moderate risk as known records (some across multiple aquifer compartments) as it was not present within the proposed mine pit, however it could still be impacted by groundwater drawdown should its affect be realised in this area.

With regard to direct loss and degradation of habitat, mining will result in the direct removal of below water table habitat for stygofauna. This includes permanent loss of stygofauna habitat due to blasting and excavation, with habitat beyond the area being mined potentially affected by shock waves propagated from blasting and through altering underground structures (usually through rock fragmentation and collapse of voids) and causing transient increases in groundwater turbidity. However, blasting is not considered as a significant impacting activity beyond the mine pit boundary.

Potential direct impacts to stygofauna habitat, as a result of removal of surface geologies in the Mine Pit are outlined in in Figure 7-2, and summarised in Table 7-7.

Based on current geological information, the primary habitats for stygofauna are the alluvial and colluvial deposits that comprise the southern portion of the MDE and portions around the BIF landform, the proposed area affected by mining is moderate in comparison to the overall area of the formation present in the wider region. These geological formations extend beyond the deposits (both locally and regionally) and as such, do not represent isolated stygofauna habitat. The continuous nature of these geological formations indicates that stygofauna (if present), extend into continuous habitat throughout the region (where connectivity allows for dispersal of stygofauna).

Given the extent of other primary habitats (nearby surficial detritals: alluvium and colluvium and calcrete deposits, where below the water table) and other secondary habitats (fractured and weathered lower members of the Woolgah-Wadgingarra Hills where sufficiently fractured and below the water table), it would be reasonable to expect that stygofauna, if present, would be well represented across the region (where connectivity allows for dispersal of stygofauna). Assumptions made on the likely wider distribution of potentially stygobitic species in a range of habitats beyond the proposed deposit boundaries are consistent with EPA guidance. As such, stygofauna are considered to be at low risk of impact from mining.

7.6.2 Groundwater abstraction

7.6.2.1 Troglofauna

Although troglofauna cannot live below the water table, they are particularly susceptible to desiccation and require a humid atmosphere, close to 100 % saturation (Howarth 1983). Drawdown below troglofauna habitat may have the potential to impact subterranean humidity and therefore, the quality of troglofauna habitat. The extent to which humidity is affected by depth to the water table is unclear. However, given that pockets of residual water probably remain trapped throughout de-watered areas and keep the overlying substrate saturated with water vapour, dewatering is expected to have minimal impact on the humidity of potential troglofauna habitat. In fact, lowering of the water table may increase the amount of troglofauna habitat available. Troglofauna may be able to avoid the effects of a habitat drying out by moving deeper into the substrate if suitable connected habitat exists at depth.

7.6.2.2 Stygofauna

Stygofauna have also been recorded from a diverse range of aquifer habitats throughout the MDE. Despite the inferred hydrogeological discontinuities within the MDE, the majority of stygofauna species are known to occur throughout multiple aquifer compartments within the MDE or more widely within the local / sub-regional area, at least within the superficial aquifer. Based on hydrogeological information, suitable habitats for stygofauna appear to occur beneath the predicted drawdown in most hydrogeological compartments. Current groundwater modelling of the mine pit dewatering, even when using a highly conservative estimate shows only minimal drawdown of between 1 – 2 m at Lazy Well. This level of drawdown, even over an extended period is not likely to significantly impact upon the available habitat for stygofauna (Invertebrate Solutions 2020).

Table 7-8 summarises which surface geological units considered to be possible subterranean fauna and the area which will be intersected with the 1m and 5m groundwater drawdown contours, as shown in Figure 7-2.

Table 7-8 Anticipated impacts to potential subterranean fauna habitat

Likelihood of subterranean fauna habitat	Total potential habitat within approximately 20km of the Mine Pit	Directly impacted potential habitat (mine pit)		Potential habitat within 5m drawdown		Potential habitat within 1m drawdown	
	Hectares	**Hectares**	**%**	**Hectares**	**%**	**Hectares**	**%**
Likely	21,620.03	102	0.47	6,508.99	30.10	10,651.85	49.26
Possible	160,139.76	45.91	0.02	20,429.2	12.75	33,683.36	21.03

7.6.3 Changes to hydrological regimes and water quality

Changes to hydrological regimes and not anticipated to impact troglofauna as they are in-ground, above the water table dwelling organisms. While contamination of groundwater (discussed in Section 7.6.4) is considered unlikely due to acid or metalliferous drainage, spills of chemical and hydrocarbons may affect air quality within troglofauna habitat. This may be the result of the volatilisation of organic compounds, or consumption of oxygen within voids due to oxidisation of contaminants, or impacts on food and nutrient sources (discussed in Section 7.6.5).

Stygofauna are particularly vulnerable to changes in hydrological regime and water quality as they dwell beneath the water table. A lowering of the water table will result in a direct loss of habitat, and will indirectly impact on stygofauna populations by removing potential connections between voids and geologies. Contamination of groundwater is unlikely due to acid or metalliferous drainage, however spills of chemicals and hydrocarbons are likely to impact on stygofauna if the contamination is present in areas of significance.

7.6.4 Groundwater contamination

Groundwater quality has the potential to decline during mining activities due to contamination. Sources of contamination include hydrocarbons and other chemicals, and acid, metalliferous and/or saline drainage from waste dumps and DPWF. Impacts from hydrocarbons and chemicals are reduced by appropriately bunding fuel depots and chemical storage facilities as well as having effective spill clean-up equipment available and therefore is not considered a significant risk. Contamination of groundwater from acid or metalliferous drainage is not anticipated at Yogi (discussed further in Section 8.6.2. Any potential for subterranean fauna population reduction as a result of indirect impacts of mining, such as hydrocarbon spills, leaching from waste dumps or tailings storage is likely to be localised and may be minimised by standard engineering and management practices.

7.6.5 Loss of food and nutrient sources

Loss of food or nutrients due to changes in groundwater levels or water quality may indirectly impact on subterranean fauna by reducing their availability for utilisation. Changes in water quality may not be suitable for stygofauna prey, and changes to groundwater levels may reduce the accessibility of food to stygofauna.

7.6.6 Cumulative impacts

A review of the environmental approval documentation that is publicly available of the other developments within proximity to the site (as listed in Section 2.4.7) was completed and a summary of their impacts have been provided in Table 7-9.

Based on the distance of Yogi Mine to other developments in the region (greater than 20 km) there are assessed to be no cumulative impacts relating to the implementation of the Proposal.

Table 7-9 Comparison of subterranean fauna impacts between other mining projects in the vicinity of the Yogi mine

Project	Karara Iron Ore Mine	Mount Gibson Iron Ore Mine	Shine Iron Ore Project	Mummaloo Project
Variable Company	Karara Mining Ltd	Mount Gibson Mining Limited	Gindalbie Metals Ltd	Top Iron Pty Ltd.
Type	Magnetite Iron Ore	Iron Ore	Iron ore	Iron Ore
Location	Shire of Perenjori 215 east south east of Geraldton	Mount Gibson Range 270 km east south east of Geraldton	Shire of Yalgoo 68 km south of Yalgoo 290 km south east of Geraldton	Shire of Yalgoo Approx. 300 km south east of Geraldton.
Subterranean fauna impacted	1 troglobitic specimen (juvenile pseudos) No Stygofauna were collected within the development envelope.	Stygobitic fauna not identified Localised reduction in abundance of Troglofauna	Stygofauna sampling recorded stygal and aquatic nematodes from one site in the project's disturbance footprint.	Low to moderate troglofauna community abundance Low likelihood of stygofauna

7.7 Mitigation

The mitigation hierarchy (avoid, minimise, rehabilitate) has been applied to this proposal in relation to subterranean fauna.

The inherent impacts that must be managed include:

- Loss or degradation of subterranean fauna habitat
- Loss of potential habitat and species populations due to groundwater abstraction
- Loss of potential habitat and species populations due to changes to hydrological regimes
- Loss of potential habitat and species populations due to loss of nutrient or food sources.

Management and monitoring measures for the above impacts are well practiced and understood in the industry, and are considered to be effective.

Proposed mitigation measures to address the above potential impacts to subterranean fauna are outlined in Table 7-10.

Table 7-10 Mitigation measures for impacts to subterranean fauna

Impact	Mitigation measures
Loss or degradation of habitat	**Avoid** • Disturbance footprint designed to reduce disturbance to BIF landform structure. **Minimise** • An internal ground disturbance procedures and permitting system will be implemented so that disturbance footprint is adhered to. • Conduct clearing in accordance with permit and clearing procedure.
Abstraction of groundwater	**Avoid** • Abstraction of water will be avoided through the reuse of water in the slurry pipeline, which will be returned to the mine. • **Minimise** • Abstraction of water will be minimised through the design of water efficient infrastructure, such as dry-stack tailings. • The project drawdown cone will be monitored and shall not exceed 5 GLpa.
Changes to hydrological regimes and water quality	**Minimise** • Disturbance to watercourses and surface hydrology will be minimised to that required to achieve safe mine design and asset protection • Local drainage will be considered when constructing new haul roads, access tracks, hardstands, waste dumps and maintaining existing road infrastructure. This activity can be managed under the Mining Act.
Groundwater contamination	**Minimise** • Disturbance to watercourses will be minimised to that required to achieve safe mine design and asset protection • Spill control measures will be implemented on site
Loss of food/nutrient sources	**Minimise** • Minimise clearing of vegetation and construction of hardstand surfaces

7.8 Predicted outcome

7.8.1 Residual impact

A summary of residual impacts after the implementation of the proposal and the application of the mitigation measures outlined in Table 7-10 above is provided in Table 7-11.

Table 7-11 Predicted outcomes for impacts to Subterranean Fauna

Impact	Residual impact
Loss or degradation of habitat	Some permanent loss of potential subterranean fauna habitat will occur from mine construction and operations. However, subterranean fauna species are not restricted to the mine area and only a minor portion of the geological unit will be removed (96.5% remaining).
Abstraction of groundwater	Abstraction of Groundwater will be localised to the immediate vicinity of the mine pit area and the paleochannel area.
Changes to hydrological regimes and water quality	Changes to the hydrological regimes and water quality are expected to be minimal and only in the immediate vicinity of the proposal.
Groundwater contamination	With implementation of appropriate environmental management subterranean fauna values are unlikely to be affected by groundwater contamination
Loss of food/nutrient sources	The development of the proposal is unlikely to affect the overall supply of food/nutrients to subterranean fauna communities.

7.8.2 Assessment against the EPA objective

Following completion of the assessment and the residual impact outlined in Table 7-10, it is considered that the implementation of the proposal will not have significant residual impacts for Subterranean Fauna. As such, it meets the objective for this factor such that the biological diversity and ecological integrity are maintained.

7.8.3 Offsets

Based on the assessment that the Proposal will not have significant residual impacts, no offsets are proposed.

8. Terrestrial Environmental Quality

8.1 EPA objective

To maintain the quality of land and soils so that environmental values are protected.

For the purposes of EIA, the EPA defines the factor 'Terrestrial Environmental Quality' as the chemical, physical, biological and aesthetic characteristics of soils.

8.2 Policy and guidance

EPA Policy and Guidance

- *Statement of Environmental Principles, Factors and Objectives* (EPA 2018b)
- *Instructions on how to prepare an Environmental Review Document* (EPA 2018a)
- *Environmental Factor Guideline Terrestrial Environmental Quality* (EPA 2016l)
- Guidance Statement 6 – *Rehabilitation of Terrestrial Ecosystems* (EPA 2006).

8.3 Required work

The required work for the terrestrial environmental quality factor as stipulated in the approved ESD and its location within this ERD is documented in Table 8-1.

Table 8-1 Required work for Terrestrial Environmental Quality

Task No	Required work	Section
38	Mine plan documentation and information on the geochemical properties of the geology will be reviewed to develop estimates of overburden and waste rock quantities	Section 8.4.1 and 8.4.2
39	Broad characterisation of overburden and waste rock properties will be provided, in particular acid generating properties will be quantified. The characterisation will be used to identify any specific requirements needed to mitigate potential impacts associated with overburden and waste rock storage. If acid generating properties are detected, additional characterisation of the overburden and waste rock will be completed to assess potential reactivity and buffering capacity.	Section 8.4.2 and 8.6.2
40	Chemical and diesel storage, and power generation and management measures, including contingencies in the event of a spill, will be provided to ensure that contamination of land does not occur.	Section 8.6.3
41	An environment management plan will be prepared to address significant residual impacts to Terrestrial Environmental Quality that describes the proposed management, monitoring and mitigation methods to be implemented demonstrating that the design of the Proposal has addressed the mitigation hierarchy in relation to impacts (direct and indirect) on soils/lands/receiving environment. This description will contain recommendations for soil handling to minimise erosion of stockpiled soils.	Section 8.7, GHD 2019d (Appendix C)
42	The residual acts on terrestrial environmental quality for direct, indirect and cumulative impacts will be quantified, after	Section 8.8

Task No	Required work	Section
	considering avoidance and minimisation measures after considering avoidance and minimisation measures. This will include noting whether these impacts are unknown, unpredictable or irreversible, or combination or contrary to that thereof	
43	A mine closure plan will be prepared, consistent with the DMIRS and EPA Guidelines	GHD 2019c (Appendix D)
44	The ERD will demonstrate and document in how the EPA's objective for this factor can be met.	Section 8.8

8.4 Receiving Environment

This section has been prepared in alignment with the requirements of *Environmental Factor Guideline: Terrestrial Environmental Quality* (EPA 2016g).

8.4.1 Supporting terrestrial environmental quality technical studies

A materials characterisation study of the development envelope was completed as part of the development of this ERD. No other studies have been completed within the development envelope of the immediately surrounding area. A summary is provided in Table 8-2.

Table 8-2 Summary of supporting Terrestrial Environmental Quality studies

Report Title Author (Month Year)	Location	Date	Summary	Survey area relevance to Proposal
Yogi Magnetite Project, Materials characterisation assessment GHD 2019d (Appendix B)	Mine Development Envelope	May 2019	GHD undertook a materials characterisation assessment in relation to leaching risks, radioactivity and air-borne hazards of the future waste rock and processing waste facilities (processed ore). The assessment used mineralogical assay information and understanding of the site setting and risks posed by mining and storage of the materials. The assessment was based on historical reports and mineralogical/geological assay data made available by FIJV.	Assessment conducted of mine pit and waste rock.

8.4.2 Geology

The Australian continent is made up of four continental blocks the Yilgarn, Pilbara and Gawler Cratons and the Wilyama Block (Lane 2004). The MDE is located within the Murchison Province of the Yilgarn Craton. The Yilgarn Craton is comprised of geological formation from the Archaean (2.5 billion years ago) to Cainozoic ages (66 million years ago to present) and bounded by the Murgoo Gneiss Complex of the Western Gneiss Terrane in the west and the Southern Cross Province in the east. The Archaean rocks of the Murchison and Southern Cross Provinces consists of linear to arcuate greenstone belts. The greenstones comprises volcanic rocks, felsic volcanic rocks and metasedimentary rocks including cherts and banded iron formation (BIF). The granitoid rocks contain adamellites, granite, gneiss and migamite (Payne *et al*. 1998).

The main greenstone sequence present in the Yalgoo Greenstone Belt comprises the Norie Group, which consists of laterally extensive (province-wide) lava plains, banded iron formations (BIF) and associated rocks.

The rock units within the Yogi area include a sedimentary succession of thrust-thickened quartzmagnetite BIF and medium grained epiclastics. These form a prominent north-south trending ridge line which dominates the topography of the Yogi Mine Project area.

Iron mineralisation at the Yogi deposit comprises secondary magnetite mineralisation hosted within the BIFs. The BIFs, which form ridges and low hills in the area, strike north-northwest to northwest in the tenements. The BIFs dip moderately steeply towards the west in the area of the tenements.

The mine ore and waste tonnages for the life of the mine are indicated as follows:

- Waste rock: 357 Million tonnes (Mt)
- Ore material: 388.5 Million tonnes (Mt).

8.4.3 Soil landscapes

The study area is located within the Karara Hills Plains and Lake, and Yalgoo Plains soil landscape zones in the Murchison Province:

- The Karrara Hills Plains and Lake Zone is described as “Hills and ranges, sandy plains, hardpan wash plains, stony plains and salt lakes (with some mesas and plains) on greenstone and granitic rocks of the Yilgarn Craton. Red shallow loams, Red loam earths, Red deep sands and Salt lake soils with some Red shallow sands, Stony soil and Red shallow sandy duplexes” (Tille 2006).
- The Yalgoo Plain Zone is described as “Hardpan wash plains (with some sandplains, stony plains, mesas and granite outcrops) on granitic rocks (with some greenstone) of the Yilgarn Craton (Murchison Domain). Red loamy earths and Red shallow loams (often with hardpans) with Red deep sands and Red shallow sands and some shallow sandy complexes” (Tille 2006).

The Department of Agriculture and Food Western Australia (DAFWA) completed a survey of the Murchison region (Hennig *et. al.* 1994). The condition and susceptibility report of land systems within the MDE is summarised in Table 8-3.

Table 8-3 Land systems within the MDE

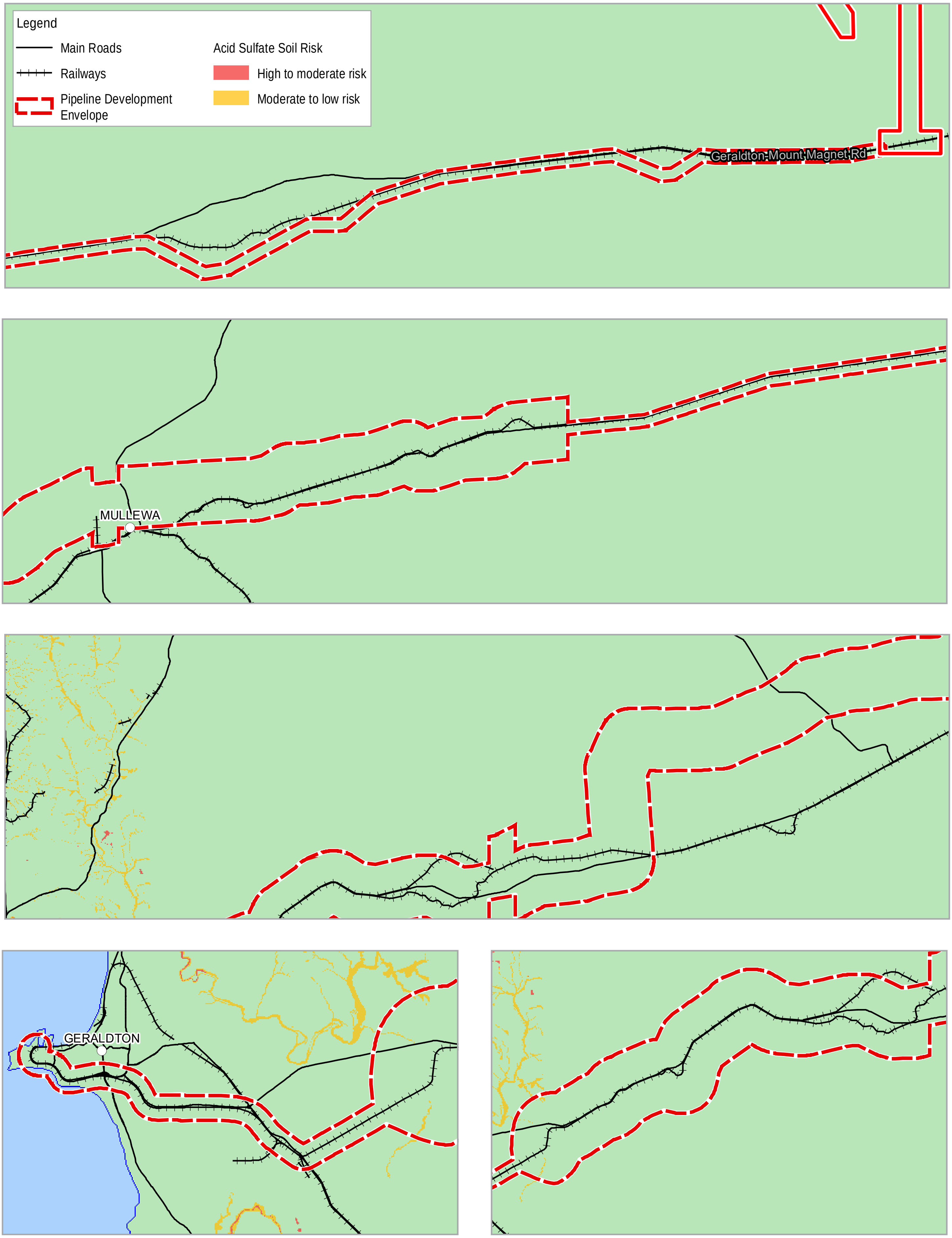
Land system	Description	Land type
Gabanintha	Ridges, hills and footslopes of various metamorphosed volcanic rocks (greenstones), supporting sparse acacia and other mainly non-halophytic shrublands.	Hills and ranges with acacia shrublands
Violet	Gently undulating gravelly plains on greenstone, laterite and hardpan, with low stony rises and minor saline plains; supporting groved mulga and bowgada shrublands and patchy halophytic shrublands.	Stony plains with acacia shrublands and halophytic shrublands
Tindalarra	Near level hardpan wash plains, narrow drainage lines and moderately saline drainage floors; supporting tall mixed acacia shrublands with wanderrie grasses, also minor saltbush/bluebush low shrublands.	Wash plains on hardpan with mulga shrublands
Challenge	Gently undulating gritty-surfaced plains, occasional granite hills, tors and low breakaways, with acacia shrublands.	Gritty-surfaced plains and granite tors and domes with acacia shrublands
Hamilton	Hardpan plains, stony plains and incised drainage lines supporting mulga shrublands.	Wash plains on hardpan with mulga shrublands

Acid Sulfate Soils

No Acid Sulfate Soils (ASS) were identified within the MDE.

A review of the ASS risk map along the PDE indicates that a Class 2 ASS risk area occurs within the PDE in one discrete area (Figure 8-1), southeast of Moonyoonooka, which is approximately 16 km east of the pipeline terminus at Geraldton Port. The proposed location of the pipeline does not intersect this risk area which is closely aligned with perennial stream in that area.

A Class 2 ASS risk area indicates that there is a moderate to low risk of ASS occurring within 3 m of the natural soil surface, but high to moderate risk beyond 3 m.



Paper Size ISO A4

0 2.5 5 7.5 10

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

FI Joint Venture Pty Ltd
Environmental Review Document

Acid Sulfate Soil Risk
Pipeline Development Envelope

Project No. 61-37117
Revision No. 0
Date 12 Jul 2019

FIGURE 8-1

G:\61\37117\GIS\Maps\Working\Environmental Review Document\6137117_008-1_ASSRiskPDE_rev0.mxd
Print date: 12 Jul 2019 - 14:54

Data source: GHD: Pipeline Corridor and Pipeline Development Envelope - 20190124; DWER: Acid Sulfate Soil Risk - 20180219; Landgate: Roads - 20190128, Railway - 20190304, Imagery.
Created by: cgverzosa

8.5 Potential impacts

Potential impacts that may occur to terrestrial environmental quality as a consequence of developing the proposal are:

- Direct Impacts:
  - Soil acidification as a result of disturbance of soil (Section 8.6.1)
  - Contamination of soils through spillage of reagents, chemicals, hydrocarbons (Section 8.6.3)
  - Indirect Impacts
  - Contamination of soils as a result of Acid and Metalliferous Drainage (Section 8.6.2).

8.6 Assessment of impacts

8.6.1 Soil acidification as a result of disturbance of soil

As shown in Figure 8-1 the occurrence of ASS within the PDE is limited to the river systems. The proposed Pipeline route does not intersect any ASS risk areas, although one area does occur within the PDE southeast of Moonyoonooka. This area lings with a perennial stream. Impacts relating to acidification of soil are assessed to be negligible, particularly given the soil within 3 m of the surface is only indicates to have a moderate to low risk of ASS and the design of the pipeline is not anticipated to be installed at depths greater than that.

8.6.2 Contamination of soils as a result of Acid and Metalliferous Drainage

The risks associated with acidic drainage (and secondary metals mobilisation) is based on:

- total concentration of *sulfide* the waste rock and mining void walls which may produce acid
- acid neutralising capacity (e.g. *carbonate*) of the waste rock and mining void walls.

Where sulfide (acid) is in excess to that of acid neutralising capacity (buffer), potential exists for the material to leach acid and metals, which may impact the soils, groundwater and surface water environments.

The orebody and waste material exhibits relatively low concentrations of acid producing potential (low sulfide concentrations 0.11% S) (GHD 2019d). Based on this it is unlikely that strong acidic conditions will develop. On this basis the waste rock and ore is unlikely to undergo sulfide style alteration/mineralisation.

Increased concentrations of dissolved metals over more than a magnitude are not anticipated, given that the low risk of strong acidic conditions persisting. However, the potential exist for elevated dissolved metal concentrations to occur even under mild acid conditions. Therefore ongoing management and testwork will be required through the life of the mine to limit potential exposure of potential contamination of soil from AMD.

8.6.3 Contamination of soils through spillage of reagents, chemicals, hydrocarbons

The proposal will require the use of various hydrocarbons (such as diesel) and other reagents or chemicals. Inappropriate management of these products, particularly hydrocarbons, has the potential to result in spills which may result in soil contamination.

With the application of management measures, as outlined in the EMP (GHD 2020d, Appendix C), the risks of substantial contamination are minimal.

8.7 Mitigation

The mitigation hierarchy (avoid, minimise, rehabilitate) has been applied to this proposal in relation to terrestrial environmental quality.

The inherent impacts that must be managed include:

- Contamination of soils due to AMD
- Contamination of soils due to spillage of reagents, chemicals and hydrocarbons.

Management and monitoring measures for the above impacts are well practiced and understood in the industry, and are considered to be effective.

Proposed mitigation measures to address the above potential impacts to terrestrial environmental quality are outlined in Table 8-4.

Table 8-4 Mitigation measures for impacts to terrestrial environmental quality

Impact	Mitigation measures
Soil acidification as a result of disturbance of soil	**Minimise** • Minimise disturbance of PASS • Follow appropriate procedures for use of buffer material (i.e. lime) in trench construction • Sample collection (mineralogical/assay) and laboratory analysis of the hanging wall and footwall materials and other underrepresented rock types to further understand the leaching potential of the waste rock and ore prior to the beginning of mining. • Ongoing monitoring throughout life of mine to be undertaken to evaluate potential for waste rock and ore to generate acid mine drainage. This will include surface water monitoring and groundwater bore monitoring.
Contamination of soils as a result of Acid and Metalliferous Drainage	**Avoid** • Waste rock dumps to be designed to include drainage management in order to capture and monitor runoff from the waste rock dumps to avoid runoff discharging into watercourses **Minimise** • Minimise waste rock handling • Ongoing monitoring throughout life of mine to be undertaken to evaluate potential for waste rock and ore to generate acid mine drainage. This will include surface water monitoring and groundwater bore monitoring. • Sample collection (mineralogical/assay) and laboratory analysis of processed material throughout mining operations to further understand its leaching potential.
Contamination of soils through spillage of reagents, chemicals, hydrocarbons	**Avoid** • Maintenance work to be undertaken on appropriate hardstand areas to prevent spills infiltrating into soils • Chemicals used on-site to be stored in an appropriate manner **Minimise** • Undertaking refuelling of mobile fleet in accordance with appropriate procedures

8.8 Predicted outcome

8.8.1 Residual impact

A summary of residual impacts after the implementation of the proposal and the application of the mitigation measures outlined in Table 8-4 above is provided in Table 8-5.

Table 8-5 Residual impacts to Terrestrial Environmental Quality

Impact	Residual impact
Soil acidification as a result of disturbance of soil	Soil acidification is unlikely from the construction of the trenches through ephemeral watercourses with the application of standard management techniques and mitigation measures applied based on the outcomes of further materials testing prior to the beginning of mining and monitoring throughout the life of mine.
Contamination of soils as a result of Acid and Metalliferous Drainage	AMD is considered unlikely based on the low sulfur content of the ore and waste material. However, proactive management measures will be applied based on further materials testing and monitoring to ensure that Terrestrial Environmental Quality values are not significantly affected.
Contamination of soils through spillage of reagents, chemicals, hydrocarbons	Soil contamination from spills is unlikely to result in significant environmental impacts.

8.8.2 Assessment against the EPA objective

Following completion of the assessment and the residual impact outlined in Table 8-5, it is considered that the Proposal will not have significant residual impacts on Terrestrial Environmental Quality. As such, it meets the objective for this factor such that the environmental values associated with the quality of land and soils are maintained.

8.8.3 Offsets

Based on the assessment that there will be no significant impact to Terrestrial Environmental Quality values, no offsets are proposed.